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(54) **Friction welder having a drive which produces orbital motion**

Reibungsschweissgerät mit Antrieb für eine orbital schwingende Bewegung

Appareil de soudage par friction comportant un dispositif d'entraînement produisant un mouvement orbital

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(56) References cited:

CH-A- 585 585	DE-A- 1 965 755
DE-C- 807 848	FR-A- 852 301
GB-A- 917 684	GB-A- 1 569 410
GB-A- 2 189 654	US-A- 2 960 317
US-A- 3 920 504	US-A- 4 086 122
US-A- 4 331 263	US-A- 4 811 835

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Description

[0001] The present invention relates to welding apparatus and particularly to an electromagnetically driven welder which can be operated to generate orbital forces and deliver them in a plane in which the joint of the parts to be welded is located. The invention also relates to an electromagnetic motor, especially adapted for use in the welder, for driving a part to be welded with orbital motion which motion is constrained to be in a plane without substantial out of plane motion.

[0002] Orbital motion may be expressed mathematically as follows in Cartesian coordinates x, y, and z for motion in x-y planes: x_0, y_0, and z_0 are positional coordinates at rest; t is time in seconds; w is radial frequency in radians per second; x(t), y(t) and z(t) are positional coordinates while moving, where $x(t) = x_0 + A \sin wt$, $y(t) = y_0 + B \sin wt$, $z(t) = z_0$, and A = B. If $A \neq B$, the orbital motion is elliptical.

[0003] The plane z = 0 is designated "the " orbital plane, and is the plane in which the orbital force is generated. Any value of z = 0 decribes another parallel orbital plane. It is seen that a particle in any orbital plane z_0 remains in that plane, since z(t) is constant.

[0004] An orbital force may be described as a force vector of constant magnitude, rotating in the orbital plane about an axis perpendicular thereto.

[0005] Throughout orbital planes, the motion remains the same (displacements, velocity and acceleration vectors are constant) irrespective of the at-rest coordinates x_0, y_0 and z_0.

[0006] The plane or planes to which the orbital forces are delivered and within which orbital motion due to such forces is constrained, is referred to as an orbital plane. The orbital force rotates in the orbital plane about an axis perpendicular thereto.

[0007] The welder provided by the invention is especially suitable for use in the welding of thermoplastic parts by means of forces (either orbital or translational vibratory forces) which induce friction heating in the parts at the joint (the interface of the surfaces to be welded) so as to cause the parts to fuse at their interface surfaces and bond together as the parts cool. Other applications of the invention and of the electromagnetic orbital drive motor are also possible.

[0008] Friction welders which operate in a translational (reciprocating) vibratory mode are commercially available. Such welders may be electromagnetically driven (see U.S. Patent 3,920,504 issued November 18, 1975) or hydraulically driven (see Bouyoucos, Behnfeldt and Selsam, U.S. Patent 4,086,122 issued April 25, 1978).

[0009] GB-A-1 569 410 relates to "Electric Storage Batteries" and discloses a method of manufacturing such batteries. The method comprises friction welding of a lid of the battery to the box thereof. Therein, the box is retained by a first die part while the lid is held by a second die part which is carried by a platen which in turn is supported by resilient bars depending from a carrier. Positioned on opposite sides respectively of the platen are a pair of electromagnets, the windings of which are connected to an a.c. supply so that, when the supply is energized, the platen is moved by magnetic attraction toward the electromagnets alternately. The lid is thereby caused to undergo linear reciprocating movement relative to the box in the plane of the open end of the box and parallel with the partition walls. Further, it is stated that, as a further alternative, the lid could be caused to move along a Lissajous figure such as an orbital path. No indication is given about how to achieve any such motion other than the above described linear reciprocating movement. It is only mentioned that "in such cases, appropriate changes are made to the widths of the abutment surface and the ribs to accommodate such movements".

[0010] US-A-3 920 504 teaches a conventional linear reciprocating friction welding apparatus. While the coil windings are connected to a three-phase alternating current source of power, they are designed and wired for providing a Scott T-connection coil arrangement which converts three-phase input power to two-phase output power. Thus, in effect, the two coils cannot produce anything else than linear reciprocating movement of one workpiece with respect to the other workpiece. In fact, as an alternative, a direct current supply in combination with a switching means is suggested for use to alternatingly energize the magnet coils. Further, it is stated that "it is apparent that by providing additional electromagnetic generating means and suitably energizing the magnets in timed relation the platform can be made to undergo two-dimensional motion in a plane parallel to the mating surfaces, for instance, circular or elliptical motion." However, no further indication is given of how to achieve this result.

[0011] Neither hydraulic nor electromagnetic drivers suitable for friction welding have heretofore been available which are capable of orbital forces, and particularly forces substantially constrained to a plane in which the surfaces at the interface of the parts at which the weld joint is to be formed can be restricted.

[0012] Orbital welding has advantages over linear vibration welding where the forces are translational and drop to zero velocity (stop) at the end of each displacement in an opposite direction. This is because frictional welding is a resistance process and the heat is proportional to the product of the resistance forces and the relative velocity of the parts. In orbital motion, the velocity remains constant as the parts are rubbed and heated to melting temperature. It is therefore possible to generate the same heat as is generated with reciprocity welding with less displacement of the parts and with less force than is the case for reciprocating welding. The peak displacement and velocity requirement is reduced by 29% (1/square root of 2). Reduction in diplacement enables the use of smaller weld flanges on the parts to be welded. With a vibratory or reciprocating weld, the parts stop at either end of a vibration cycle so that the heat generation is cyclic. With orbital motion the welder produces constant heat at the joint because the velocity magnitude is constant, thus faster welding with less displacement is possible using the orbital process.

[0013] Orbital welding also has advantages over spin welding in which parts are spun about an axis. In spin welding, rotational forces and heating effects on the parts vary with the radial distance from the center of rotation of the spinning parts. The velocity and heating effect is not uniform in a radial direction across the interface where the parts are to be bonded. Spin welding is also generally restricted to applications where a part is circular in geometry.

[0014] There are parts, however, which are not amenable to welding with orbital motion, but are amenable to welding by linear motion. Therefore it is desirable to provide a welder which can execute either linear, reciprocating or orbital motion, as may be desired. Reciprocating welding is readily accomplishable in a plane in which the joints are disposed, usually held in a welding head on a platen. It is difficult to achieve orbital motion without generating additional motion which is not in or parallel to the orbital plane because the platen, which holds one of the parts to be welded against the other in a press or clamping mechanism, has the tendency to tilt and cause the parts to lose contact. It is a feature of the invention to provide an electromagnetic orbital drive especially suitable for use in a friction welder wherein the motion is restricted substantially into a plane (the orbital plane).

[0015] Accordingly, it is the principal object of the present invention to provide an improved friction welder.

[0016] It is another object of the invention to provide an improved frictional welder which may be operated alternatively in a translational (reciprocating) vibratory mode or in an orbital mode.

[0017] It is the still further object of the present invention to provide an improved electromagnetic orbital drive and a friction welder wherein the drive is included and wherein orbital motion is provided restricted substantially in an orbital plane.

[0018] Briefly described, apparatus embodying the invention for friction welding of parts at an interface therebetween includes means for driving at least one of the parts with orbital movement with respect to another of the parts while the parts are held in contact at the interface (where the welded joint is is to be formed). The driving means comprises electromagnetic force generating means which produces orbital force in an orbital plane. The welder also includes means for mounting the part which executes orbital motion in response to the orbital force so as to locate the interface to be welded between the parts in the orbital plane. The mounting means is an array of flexural elements preferably having like stiffness in all directions parallel to the orbital plane; for example, rods encompassing the electromagnetic orbital drive which are connected at one end to a plate which is driven by the orbital force and at the other end to a massive support.

[0019] It has also been found in accordance with the invention, that the orbital velocity (the velocity of the orbital motion of the orbitally drive member) can be controlled in response to the third harmonic of current which is applied to the electromagnetic orbital drive. By responding to the third harmonic, the frequency of the AC power is controlled so as to be at a desired frequency, preferably the frequency at which the orbital drive structure including its flexural (spring) supports, is resonant.

[0020] The foregoing and other objects features and advantages of the invention as well as presently preferred embodiments thereof will become more apparent from the reading of the following description in connection with the accompanying drawings in which:

FIG. 1 is a sectional front view of a friction welder embodying the invention; the section being taken along the line 1-1 in FIG. 2;

FIG. 2 is a plan view of the welder shown in FIG. 1 partially broken away to illustrate the electromagnetic drive motor and the support which provides orbital motion in an orbital plane in greater detail;

FIG. 3 is a more detailed diagram illustrating the orbital drive motor and the connections of the coils thereon, the coils being shown schematically in the Figure;

FIG. 4 is a schematic diagram illustrating delta wiring of the coils of the orbital motor for full output and minimal current distortion;

FIG. 5 is a schematic diagram showing wye wiring of the coils of the electromagnetic orbital motor which provides one-third the output force of the delta connected coil configuration shown in FIG. 4;

FIG. 6 is a schematic diagram similar to FIG. 3 showing the stator of an electromagnetic orbital motor with coils which can selectively be connected to provide orbital force or vibratory translational (reciprocating) force of half the magnitude of the orbital force provided by the configuration shown in FIG. 3;

FIG. 7 is a schematic diagram showing the connections of the coils to provide reciprocating force with peak magnitude equal to half the peak orbital force;

FIG. 8 is a block diagram, schematically showing a velocity control system for the electromagnetic orbital/vibrational motor illustrated in the preceding figures;

FIG. 9 is a front view partially broken away to illustrate an orbital/vibrational friction welder having two electromagnetic orbital drive motors which can be operated in the orbital or reciprocating drive mode;

FIG. 10 is a plan view of the welder shown in FIG. 9; and

FIG. 11 is a schematic diagram of the circuit of the two orbital electromagnetic drive motors with switching so as to select either net orbital or vibrating (reciprocating force).

[0021] Referring more particularly to FIGS. 1 and 2, there is shown a framework 10 of a friction welder made up of steel tubes. A massive support plate 12 is mounted on vibration isolation or shock mounts 14, thereby mounting the plate 12 and the rest of the welder on the framework 10. The mass of the plate 12 is desirably much greater than the mass of the moving parts of the system, and, for example, may be 90.8 Kg (200 pounds) as compared to the mass of the moving parts which may be approximately 11.35 Kg (25 lbs). The plate 12 may for example be steel 5.08 cm (2 inches) in thickness and 50.8 cm (20 inches) in diameter. The sizes mentioned are for an exemplary welder. It will be appreciated that the electromagnetic orbital drive may be made smaller, if desired, so as to enable the construction of reduced scale vibration welders, much smaller than vibration welders of the type presently commercially available and as described in the above-referenced patents. For example, the weld head 16 of the welder may be reduced in size to a size comparable of ultrasonic welding heads. Where higher force output is desired, a plurality of drivers which provide forces which add may be used. A welder using two drivers is described hereinafter in connection with Figures 9 through 11.

[0022] The weld head includes a tubular structure 18 having an opening in which the electromagnetic driver or motor 20 is contained. A flange 22 connects the tubular structure to the massive support plate 12.

[0023] The motor 20 is adapted to be driven by three phase AC power applied to coils 24, 26 and 28 on a stator 30. (See also, FIG. 3.). The stator 30 is a single body of magnetic material made up of laminations of steel of the type used in electric motors which are disposed in a stack mounted by bolts 32 on a ring 34 which is attached, as by welding to the tubular structure 18. The stator 30 is generally triangular in cross section with the apexes of the triangular shape cut off for conservation of material and space. The stator defines a ring which affords a magnetic return path for flux generated by the coils. Poles 38, 40 and 42 around which the coils 26, 28 and 24, respectively are wound, project inwardly towards a central axis which is defined by bisectors of each angle of the triangular shape; the triangular shape being equilateral. The coils may be wound in two sections and connected together for ease of installation. While it is preferrable to use coils disposed around the stator poles 44, 46 and 48 as shown, the coils may be wound around the sections of the corners of the stators where the bolts 32 are shown. In a typical motor, the area of the faces 44, 46 and 48 of the stator poles may be approximately 3 square inches. The number of turns in a typical motor may be 200. The motor has an armature 50, which like the stator, is a single body of magnetic material made up of a stack of laminations which are clamped between a washer 52 and a stub 54 by a bolt 56.

[0024] The armature is generally triangular in cross-section and has pole faces along each of its sides (sides of an equilateral triangular shape). These faces 58, 60 and 62 (see FIG. 3) are opposed to and separated by air gaps from the stator pole faces 44, 46 and 48, respectively. The width of each gap may, for example, be 1.27 mm (0.050 inches). All of the pole faces and the gaps are symmetrically disposed about the central axis of the armature. This axis is the longitudinal, central axis of the bolt 56. The width of the gap is desirably greater than the peak orbital motion of the armature, which may for example be 0.53 mm (0.021 inches), so that the armature does not strike the stator.

[0025] The armature is connected by bolts, one of which 64 is shown in FIG. 1, to a drive plate 66 which may be circular and have a tubular flange 68 which is bolted to the platen 70 of the welder. This platen is connected to an orbitally moveable part 72 of a tool or fixture 76 which carries one of the parts 78 which is to be welded at weld flanges 80 to another part 82. The weld flanges have weld surfaces which define the interface 84 of the parts. The parts may be of thermoplastic material. The lower part 82 is fixedly held in the lower section 74 of the tool or fixture 76.

[0026] This lower half is mounted on a clamp plate 86 which is reciprocated vertically by hydraulic cylinders 88 so that the parts can be clamped together at the interface with sufficient force that when the upper part 78 is moved orbitally by the motor 20 heat is generated which causes melting to take place at the interface.

[0027] In order to prevent tilting of the armature 50 at the interface, (causing loss of contact of the weld surfaces and reduced frictional forces which are developed as the upper weld part 78 executes orbital motion) the armature 50 and hence the upper part 78 is maintained in a horizontal orbital plane as shown at 84. This is accomplished by a flexural, spring support system for the armature 50, the drive plate 66 the platen 70 and the fixture part 72 which is attatched thereto. This flexural support is provided by a symmetrical array of rods 90 mounted outboard of the stator - armature system to stabilize the platen motion and maintain the orbital forces in the orbital plane. These rods are elements which provide equal stiffness in the direction around their axes (i.e., parallel to the orbital plane). Circumferentially adjacent ones of the rods 90 are staggered so that alternate rods are radially, closer and further from the axis of the motor 20. This arrangement provides a constraint against tilting motion out of the orbital plane. The array also defines stiffness which with the mass of the orbitally moveable parts (the armature 50 and the fixture part 72 and the parts connected thereto) is a mechanical system resonant at the frequency of orbital motion. This is twice the frequency of the AC power which is applied to the coils 24, 26 and 28 on the stator poles 38, 40 and 42. The frequency motion is doubled because the electromagnetic forces are proportional to the square of the flux in the air gaps between the pole faces and therefore are proportional to the square of the voltage applied to the coils. It will be appreciated that orbital motion occurs because the forces on the armature are generated by the three phase flux which, because of frequency doubling, is 60° out of phase at each of the poles. At any point in the orbital plane this force produces motion which can be resolved into displacement, velocity or acceleration vectors which are in the same direction and can each be represented by vectors (parallel to the orbital plane or, in other words, perpendicular to the orbital axis) and are proportional in amplitude to the sine and cosine of twice the AC power line frequency (i.e., these vectors rotate at twice the frequency of the AC power). As discussed above, orbital motion is expressed mathematically in terms of position coordinates x, y and z in the xy orbital plane (z=0 in the orbital plane and has a finite value to denote orbital planes parallel thereto); where x and y are measured at an arbitrary origin in the orbital plane; x_0, y_0 and z_0, are positional coordinates at rest; t is time and seconds and ω is radial frequency in radians per second, the motion in the orbital plane is $x(t)=x_0 + A \sin \omega t$ and $y(t)=y_0 + B \cos \omega t$. When A and B in the equations for x(t) and y(t) are different, the orbital motion is elliptical. Throughout the orbital plane(s), the motion remains the same (the displacements, velocity and acceleration vectors are constant) irrespective of the distance in the plane from any arbitrary origin to a point where the orbital motion is observed.

[0028] Referring to FIGS. 3, 4 and 5, it will be seen that the coil 24 is designated as "coil 1," the coil 26 is designated as "coil 2" and the coil 28 is designated as "coil 3." These coils may be connected in delta with the ends of the windings indicated by the numerals within circles connected together as shown in FIG. 4 and the ends of the delta connected coils connected to the three phase power lines indicated as $\phi 1$, $\phi 2$ and $\phi 3$. Alternatively, and if less force is desired than for delta wiring, the coils may be connected in wye configuration as shown in FIG. 5. In wye mode, the force output is one-third the force output with delta connection and the current drawn from the lines is also reduced by one-third. The delta connection at resonance has a third harmonic of coil current which is 16 dB below the fundamental of the AC current, while the current from the AC drive has a fifth harmonic 28 dB below the fundamental. It is therefore seen that the delta connection reduces the harmonics in the current from the AC drive.

[0029] Translational (reciprocating) vibratory force may be selected if two orbital motors are mechanically connected to the same load (the same drive plate) as shown in FIGS. 9, 10 and 11. Alternatively a single phase drive may be used with a single orbital driver to obtain reciprocating (linearly vibrating) force in a direction towards one of the pole faces. This may be accomplished by dividing each coil into two sections so that coil 1 is divided into coils 1A and 1B, coil 2 is divided into coils 2A and 2B and coil 3 is divided into coils 3A and 3B. The terminals of these coils are correspondently marked 1A1, 1A2 through 3B1, 3B2, as shown in FIGS. 6 and 7. By selectively connecting, for example coil 1A and 1B in parallel and the other coils in series linear vibrational (reciprocating) force is generated on the armature which is directed towards the face of the pole around which coil 1 is wound. When single phase AC power (as indicated in FIG. 7, for example, the power between phase two and phase three of the AC lines) is applied across the parallel connected coils 1A and 1B, the reciprocating force is approximately one-half the peak magnitude of the orbital force. Suitable switches may be used to connect the coil sections so as to receive single phase drive power and into the series and parallel connections so as to provide the linear vibrating force in the desired one of the three directions. With the configurations shown in FIGS. 1 and 2, it will be desirable for the parallel connected coils to be those on pole 38. Then the linear direction of vibrating reciprocation will be along the line between the ends 92 and 94 of the welder.

[0030] Referring to FIG. 8, there is shown a velocity control system for the electromagnetic orbital drive motor illustrated in the preceding figures.

[0031] It has been discovered in accordance with the invention that the third harmonic of the current passing through a coil of the motor may be used to monitor the orbital velocity. The orbital velocity may then be used to control the frequency of the three phase AC power supplied to the coils of the motor 20. The frequency of the power is controlled by a variable frequency motor controller 96 which may be of the type which is commercially available and is driven by an analog, slowly varying or dc signal (FREQ) which controls the frequency of the three phase output (3ϕ) on the output lines from the controller 96 which provide the motor drive volts to the motor 20. The voltage E_1 and the current I_1 across one of the coils is used and applied to a velocity resolver 98 which is a circuit which performs analog or digital computations in accordance with the following equations:

$$
\begin{aligned}
|v| &= K * \left|I_1^{(3)}\right| * \mathrm{FREQ}^2 / \left|E_1^{(1)}\right| \\
&= \text{orbital velocity magnitude} \\
\measuredangle\mathrm{LOAD} &= \measuredangle E_1^{(1)} - \measuredangle I_1^{(3)} \quad = 0 \text{ at resonance} \\
&\qquad\qquad\qquad\qquad\quad < 0 \text{ at resonance} \\
&\qquad\qquad\qquad\qquad\quad > 0 \text{ at resonance}
\end{aligned}
$$

From the equations it will be apparent that the load phase angle is represented as the phase angle between the fundamental of the voltage across the coil and the third harmonic of the current in the coil $E_1^{(1)}$ and $I_1^{(3)}$. The outputs from the velocity resolver are signals indicating the velocity of the load and the phase angle of the load. The load is carried by a flexural support system, which with the mass of the load and the stiffness of the support system, defines the resonant frequency of the mechanical system. The phase angle is 0 at resonance, negative below resonance and positive above resonance. The system uses a frequency controller 100, which may also be an analog computer or digital computer, which responds to the difference between the velocity output |v| from the resolver 98 and the phase angle of the load. As long as the drive frequency (twice the AC power frequency in the orbital motor illustrated in the preceding figures) is below resonance, increasing the drive frequency increases the velocity. As long as the load phase angle is negative, the frequency is below resonance. When the load angle reaches 0, the system is at resonance and further increases in frequency will not increase the velocity. The frequency controller therefore operates in accordance with the following equations:

$$\text{If } (|v| < v_0) \text{ and } (\phi\ \text{LOAD} < 0)$$
$$\text{then increase FREQ}$$
$$\text{If } (|v| > v_0) \text{ then decrease FREQ}$$

and provides the FREQ controller input signal to which the controller 96 responds.

[0032] In addition, for velocity control, the current across all three coils may be monitored to give an average value of velocity as measured by each coil, thereby improving control resolution.

[0033] Referring to FIGS. 9, 10 and 11 there is shown a friction welder 102 having two electromagnetic orbital drive motors 104 and 106, each of a design similar to the motor 20 of the welder shown in FIGS. 1, 2 and 3. This welder has a massive support plate 108 mounted by shock mounts 110 on a framework 112. A hydraulically driven reciprocating platen 114 carries the stationary fixture part 116. The stationary part to be welded is illustrated as a thin thermoplastic plate 118. The part 120, which is to be moved, is mounted in the upper part 122 of the fixture. This part 122 is connected to a platen 126. The platen is connected to drive plates (not shown) or directly to the armatures 128 and 130 of the motors 104 and 106.

[0034] FIG. 11 illustrates the coils: coil 1, coil 2 and coil 3 of the motor 104 and the coils coil 1', coil 2' and coil 3' on the stator of the motor 106. A three pole switch changes the connections to coils 1', 2' and 3' of the three phase power which are applied to the lines indicated at $\phi 1$, $\phi 2$ and $\phi 3$. This is a mode selector switch. The switch provides for the generation of orbital force at twice the force provided by each motor onto the drive plate 126. Alternatively the motors may be operated with the mode selector switch to produce a reciprocating force of peak magnitude twice the force produced by each motor towards any pole. In other words, the peak magnitude of the sum of the forces applied by the motors to the drive plate 126 and then to the movable part 120 equals twice the peak magnitude of the orbital force of a single motor.

[0035] From the foregoing description, it will be apparent that there has been provided improved friction welders and improved orbital electromagnetic drivers (motors) which are especially suitable for use therein. Variations and modifications in the herein described welders and motors, within the scope of the invention as defined in the claims, will undoubtedly suggest themselves to those skilled in the art. Accordingly, the foregoing description should be taken as illustrative and not in a limiting sense.

Claims

1. Apparatus for friction welding of parts (78, 82) at an interface (84) therebetween which apparatus comprises:

means (16) for driving one of said parts (78) with orbital movement with respect to another of said parts (82) while said parts are held in contact at said interface, said driving means (16) comprising electromagnetic force generating means (20, 30, 50, 24, 26, 28) which produces orbital force in an orbital plane, and
means (64, 66, 68, 70, 72, 90) for mounting said one of said parts to execute orbital motion in response to said orbital force when said interface (84) is in said orbital plane,

wherein said electromagnetic force generating means comprises an orbital motor (20) comprising
a single body of magnetic material providing an armature (50) having a central axis perpendicular to said orbital plane and a plurality of poles distributed circumferentially by 360°/N, where N is the number of said poles, about said axis, N is equal to or greater than 3, and

a stator (30) being disposed around said armature (50), having a plurality of poles (38, 40, 42) each opposed to a different one of said armature poles, said armature (50) being attached to said mounting means to said one part (78) to cause said one part to execute orbital motion in said orbital plane,
wherein said mounting means (16) comprises an array of flexural means (90) for supporting said armature (50) for orbital motion in a plane, said flexural means (90) being mounted outboard of said orbital motor (20).

2. The apparatus according to claim 1 wherein said armature and stator poles are perpendicular to said orbital plane and said electromagnetic force generating means (20) includes magnetic flux generating coils (24, 26, 28) magnetically coupled to said stator poles (38, 40, 42) for establishing flux which is directed through said armature (50) along said axis.

3. The apparatus according to claim 2 wherein said stator (30) is a single body of magnetic material ringing said armature (50) from which said stator poles (38, 40, 42) extend and which defines a return path for said flux.

4. The apparatus according to claim 3 wherein said stator poles (38, 40, 42) and said armature poles execute relative displacement while executing orbital motion and have opposed faces (44, 46, 48; 58, 60, 62) spaced from each other by air gaps, the width of said gaps as measured along a line perpendicular to said faces being greater than the peak of said displacement of said armature (50) in response to said orbital force.

5. The apparatus according to claim 4 wherein said armature (50) is generally triangular in a plane perpendicular to said axis, each of said armature faces (58, 60, 62) being along a different side of said triangle.

6. The apparatus according to claim 5 wherein said poles (38, 40, 42) are 120° apart, said apparatus further comprising means for applying different phases of three phase AC power to each of said stator coils (24, 26, 28).

7. The apparatus according to claim 3 wherein said armature body and said stator body comprise separate stacks of laminations of magnetic material.

8. The apparatus according to claim 6 wherein said coils (24, 26, 28) are connected in delta configuration.

9. The apparatus according to claim 6 wherein said coils (24, 26, 28) are connected in wye configuration.

10. The apparatus according to claim 2 wherein said mounting means (16) comprises a plate (66) to which said armature (50) is connected, said flexural means (90) supporting said plate (66) for orbital motion in a plane together with said armature (50), and a massive support (12) for fixedly anchoring said stator (30) and for anchoring said flexural means (90).

11. The apparatus according to claim 10 wherein said flexural means (90) comprises spring means having the same stiffness in all directions in the plane in which said plate (66) executes its orbital motion.

12. The apparatus according to claim 11 wherein said electromagnetic force generating means (20) includes stator coil means (24, 26, 28) operated by AC power, and wherein said mounting means (16) including said plate (66) and said armature (50) and said one part (78) has a total mass and stiffness which defines a frequency of resident vibration approximately at twice the frequency of said AC power.

13. The apparatus according to claim 11 wherein said spring means (90) are a plurality of rods disposed around and paralleling said axis, said rods (90) being fixed at one end thereof to said support (12) and at the other end thereof to said plate (66).

14. The apparatus according to claim 13 wherein different ones of said rods (90) are displaced radially at different distances from said axis.

15. The apparatus according to claim 14 wherein said rods (90) are disposed symmetrically about said axis with rods which are adjacent to each other in a direction circumferentially about said axis being respectively closer and further away from said axis in a radial direction, thereby counteracting tilting of said plate (66).

16. The apparatus according to claim 13 wherein said support (12) comprises:

a support body more massive than said armature (50) and said mounting means (16),
a tubular structure (18) connected to said plate (16) and having an opening extending along said axis, said tubular structure (18) being connected to said support body (12), said rods (90) being disposed in said opening in said tubular structure (18) and being fixedly connected thereto at one end of each of said rods (90).

17. The apparatus according to claim 16 wherein said electromagnetic force generating means (20) including said armature (50) and said stator (30) are disposed in said opening in said tubular structure (18).

18. The apparatus according to claim 17 wherein said welding apparatus has a frame work (10) connected to said support body (12).

19. The apparatus according to claim 18 further comprising a fixture (76) for receiving said one part (78) including a platen (70) connected to said plate (66), and another platen reciprocally movable along said axis for supporting the other of said parts (82) and moving said parts (78, 82) into contacting relationship at said interface (84).

20. The apparatus according to claim 1 wherein said stator poles each have a plurality of coils thereon, said apparatus further comprising:

means for connecting said coils on one of said poles in parallel and the coils on the others of said poles in series,
means for connecting said series and parallel connected coils to each other, and
means for applying single phase AC power across one of said series and parallel connected coils so as to generate translational vibratory force instead of orbital force in said plane.

21. The apparatus according to claim 1 wherein said electromagnetic force generating means (20) comprises means (96, 98, 100) for controlling the velocity of said one part (78) in said orbital plane.

22. The apparatus according to claim 21 wherein said electromagnetic force generating means (20) includes at least one coil to which AC power is applied at a fundamental frequency, said controlling means (96, 98, 100) comprises means responsive to a first signal related to the magnitude of the current at the third harmonic of said fundamental frequency and a second signal related to the phase angle between the voltage across said coil at said fundamental frequency and said current at said third harmonic for controlling the frequency of said AC power.

23. The apparatus according to claim 22 wherein said controlling means (96, 98, 100) further comprises means for increasing said frequency when said second signal is negative and said first signal is below a certain magnitude and for decreasing said frequency when said first signal is above said certain magnitude.

24. The apparatus according to claim 1 wherein said interface (84) is contained in said orbital plane.

25. Apparatus (102) according to claim 1 wherein said driving means (104, 106) includes first electromagnetic force generating means (104) and second electromagnetic force generating means (106) each of which are independently capable of producing an orbital force in said orbital plane,
said apparatus further comprising means for appyling electrical power to said first and second electromagnetic force generating means (104, 106) for driving the mounting means (108, 122, 126) for said one of said parts (120) with either orbital motion or with translational vibratory motion.

26. The apparatus (102) according to claim 25 wherein
said first electromagnetic force generating means (104) includes a first motor (104) adapted to be driven by three phase electrical power and having a stator and an armature (128), said armature (128) being a single body of magnetic material, said stator surrounding said armature (128), said stator being a single body of magnetic material having three poles circumferentially displaced from each other and having a coil on each pole, each pole having a face, said armature having faces spaced circumferentially from each other and each armature face opposed to a different pole face, and
said second electromagnetic force generating means (106) includes a second motor (106) having an armature (130), a stator having three poles and a coil on each pole of said stator of said second motor,
said mounting means (108, 122, 126) including a plate (108) connected to the armature (128) of said first motor (104) and to the armature (130) of said second motor (130) at spaced locations,
said apparatus further comprising means for switching the phases of the three phase power to different ones of said coils of said first motor (104) for selectively driving said plate with orbital motion or with translational vibratory

motion.

27. The apparatus according to claim 26 wherein said mounting means (108, 122, 126) includes a platen (126) which is connected to both said first motor (104) and said second motor (106).

28. The apparatus according to claim 1 wherein said orbital motor (20) is adapted to be operated by single phase AC power and wherein each of said stator poles (38, 40, 42) has a plurality of coils (24, 26, 28) wound thereon, said motor further comprising

means for connecting said coils on one of said stator poles in parallel and the coils on the others of said poles in series,

means for connecting said series and parallel connected coils to each other, and

means for applying said single phase AC power across one of said series and parallel connected coils so as to generate translational vibrational force instead of orbital force in said plane.

29. The apparatus according to claim 28 further comprising means (96, 98, 100) for controlling the velocity of motion in said orbital plane responsive to the current and voltage across one of said coils.

30. The apparatus according to claim 29 wherein said controlling means (96, 98, 100) comprises means responsive to a first signal related to the magnitude of said current at the third harmonic of the frequency of said AC power and a second signal having a magnitude related to the phase angle between the voltage across said coil at the frequency of said AC power and the current through said coil at said third harmonic for controlling the frequency of said AC power.

31. A method of friction welding of a pair of parts (78, 82) having thermoplastic material at surfaces thereof to be welded, comprising the steps of:

providing electromagnetic force generating means (20) wherein said electromagnetic force generating means (20) comprises

a single body of magnetic material providing an armature (50) having a central axis perpendicular to said orbital plane and a plurality of poles distributed circumferentially by 360°/N, where N is the number of said poles about said axis, N being equal to or greater than 3, and

a stator (30) being disposed around said armature (50), said stator (30) having a plurality of poles (38, 40, 42) each opposed to a different one of said armature poles;

holding said parts (78, 82) with said surfaces together in contacting relationship;

generating orbital force to provide orbital motion of said armature (50) with respect to said stator (30);

maintaining said surfaces in said orbital plane while said orbital force is generated by an array of flexural means (90) mounted outboard of said electromagnetic force generating means (20);

generating frictional force to cause said surfaces of said parts (78, 82) to fuse by driving at least one of said parts (78) with said armature (50) and holding the other of said parts (82) stationary so that said at least one of said parts (78) executes orbital motion and orbits around axes perpendicular to said contacting surfaces and said frictional force is sufficient in amplitude to cause fusion at said surfaces, said orbital plane being perpendicular to said axes, and

terminating said frictional force and maintaining said parts (78, 82) which are being welded together after said frictional force terminates until they fuse together to form a weld.

Patentansprüche

1. Vorrichtung zum Reibungsschweißen von Teilen (78, 82) an einer Grenzoder Zwischenschicht (84) dazwischen, wobei die Vorrichtung folgendes aufweist:

Mittel (16) zum Antreiben eines der Teile (78) mit einer Orbitalbewegung bezüglich einem weiteren der Teile (82) während die Teile in Kontakt an der Grenzfläche gehalten werden, wobei die Antriebsmittel (16) elektromagnetische Krafterzeugungsmittel (20, 30, 50, 24, 26, 28) aufweisen, welche die Orbitalkraft in einer Orbitalebene erzeugen, und

Mittel (64, 66, 68, 70, 72, 90) zum Anbringen oder Halten des erwähnten einen der Teile, um die Orbitalbewegung ansprechend auf die erwähnte Orbitalkraft auszuführen, wenn die Grenzfläche (84) sich in der Orbitalebene befindet, wobei die elektromagnetischen Krafterzeugungsmittel einen Orbitalmotor (20) aufweisen, der seinerseits folgendes aufweist:

einen ersten Körper aus Magnetmaterial, der einen Anker (50) vorsieht mit einer Mittelachse senkrecht zu der Orbitalebene und mit einer Vielzahl von Polen umfangsmäßig verteilt um die erwähnte Achse um 360°/N wobei N gleich oder größer als 3 ist, und
einen Starter (30) der um den erwähnten Anker (50) herum angeordnet ist und zwar mit einer Vielzahl von Polen (38, 40, 42), deren jeder entgegengesetzt zu einem unterschiedlichen der Ankerpole angeordnet ist, wobei der Anker (50) an den Befestigungsmitteln mit dem erwähnten einen Teil (78) angebracht ist, um zu bewirken, dass der erwähnte eine Teil eine Orbitalbewegung in der Orbitalebene ausführt,

Wobei die Befestigungsmittel (16) eine Anordnung von biegsamen der flexiblen Mitteln (90) aufweisen zum Tragen des Ankers (50) für eine Orbitalbewegung in einer Ebene, wobei die biegsamen Mittel (90) außerhalb des Orbitalmotors (20) angeordnet sind.

2. Vorrichtung nach Anspruch 1, wobei die Anker und Statorpole senkrecht zur Orbitalebene verlaufen, und wobei die elektromagnetischen Krafterzeugungsmittel (20) magnetische Flußerzeugungsspulen (24, 26, 28) aufweisen, und zwar magnetisch gekoppelt mit den Statorpolen (38, 40, 42) zum Vorsehen eines Flusses, der durch den Anker (50) entlang der erwähnten Achse geleitet wird.

3. Vorrichtung nach Anspruch 2, wobei der Stator (30) ein einziger Körper aus Magnetmaterial ist, der den Anker (50) umringt, von dem aus sich die Statorpole (38, 40, 42) erstrecken und der einen Rücklaufpfad für den Fluss definiert.

4. Vorrichtung nach Anspruch 3, wobei die Statorpole (38, 40, 42) und die Ankerpole eine relative Bewegung oder Versetzung ausführen, während die Orbitalbewegung ausgeführt wird und sie besitzen entgegengesetzt liegende Stirnseiten (44, 46, 48; 58, 60,62) beabstandet voneinander durch Luftspalte, wobei die Breite der Spalte gemessen entlang einer Linie senkrecht zu den Stirnflächen größer ist als der Spitzenwert der Versetzung des Ankers (50) ansprechend auf die Orbitalkraft.

5. Vorrichtung nach Anspruch 4, wobei Anker (50) im allgemeinen dreieckig ist und zwar in einer Ebene senkrecht zu der erwähnten Achse, wobei ferner jede der Ankerstirnflächen (58, 60, 62) entlang einer unterschiedlichen Seite des erwähnten Dreiecks verläuft.

6. Vorrichtung nach Anspruch 5, wobei die Pole (38, 40, 42) 120° voneinander beabstandet angeordnet sind, wobei die Vorrichtung ferner Mittel aufweist, um unterschiedliche Phasen der drei-phasigen Wechselstromlesitung an jede der Statorspulen (24, 26, 28) anzulegen.

7. Vorrichtung nach Anspruch 3, wobei der Ankerkörper und der Statorkörper gesonderte Stapelschichtungen von Magnetmaterial aufweisen.

8. Vorrichtung nach Anspruch 6, wobei die Spulen (24, 26, 28) in einer Deltakonfiguration verbunden sind.

9. Vorrichtung nach Anspruch 6, wobei die Spulen (24, 26, 28) in einer Y-Konfiguration verbunden sind.

10. Vorrichtung nach Anspruch 2, wobei die Befestigungsmittel (16) eine Platte (66) aufweisen mit der der Anker (50) verbunden ist, und wobei die flexiblen Mittel (90) die erwähnte Platte (66) zur Orbitalbewegung in eine Ebene zusammen mit dem Anker (50) tragen, wobei ein massiver Träger (12) vorgesehen ist, um den Stator fest zu verankern und zum Verankern der flexiblen Mittel (90).

11. Vorrichtung nach Anspruch 10, wobei die flexiblen Mittel (90) Federmittel aufweisen und zwar mit der gleichen Steifheit in allen Richtungen in der Ebene, in der die Platte (66) ihre Orbitalbewegung ausführt.

12. Vorrichtung nach Anspruch 11, wobei die elektromagnetischen Krafterzeugungsmittel (20) Statorspulenmittel (24, 26, 28) aufweisen und zwar betätigt durch Wechselstromleistung, wobei die erwähnten Befestigungsmittel (16) einschließlich der Platte (66) und des Ankers (50) und des erwähnten einen Teils (78) eine Gesamtmasse und Steifheit besitzen, welche eine Frequenz der Eigenschwingung annähernd beim Doppelten der Frequenz der erwähnten Wechselstromleistungsquelle definiert.

13. Vorrichtung nach Anspruch 11, wobei die Federmittel (90) eine Vielzahl von Stangen sind und zwar angeordnet um und parallel zu der erwähnten Achse, wobei die Stangen (90) an einem Ende derselben mit dem Träger (12) befestigt sind und am anderen Ende derselben mit der Platte (66).

14. Vorrichtung nach Anspruch 13, wobei unterschiedliche der erwähnten Stangen (90) radial mit unterschiedlichen Abständen gegenüber der Achse versetzt sind.

15. Vorrichtung nach Anspruch 14, wobei die Stangen (90) symmetrisch um die Achse angeordnet sind, wobei die Stangen, die benachbart zueinander in einer Richtung umfangsmäßig um die erwähnte Achse jeweils dichter und weiter weg vor der erwähnten Achse in Radialrichtung angeordnet sind, wodurch dem Kippen der Platte (66) entgegengewirkt wird.

16. Vorrichtung nach Anspruch 13, wobei der Träger (12) folgendes aufweist:

einen Trägerkörper, der massiver ist als der Anker (50) und die Befestigungsmittel (16),
eine rohrförmige Struktur (18) verbunden mit der erwähnten Platte (16) und mit einer Öffnung, die sich entlang der Achse erstreckt, wobei die rohrförmige Struktur (18) mit dem Trägerkörper (12) verbunden ist, wobei die Stangen (90) in der erwähnten Öffnung der Rohrstruktur (18) angeordnet sind und
fest damit verbunden sind und zwar an einem Ende jeder der erwähnten Stangen (90).

17. Vorrichtung nach Anspruch 16, wobei die elektromagnetischen Krafterzeugungsmittel (20) einschließlich des Ankers (50) und des Stators (30) in der erwähnten Öffnung der Rohrstruktur (18) angeordnet sind.

18. Vorrichtung nach Anspruch 17, wobei die Schweißvorrichtung ein Rahmenwerk (10) aufweist und zwar verbunden mit dem Trägerkörper (12).

19. Vorrichtung nach Anspruch 18, wobei ferner eine Befestigungsvorrichtung (76) vorgesehen ist zum Aufnehmen des erwähnten einen Teils (78) einschließlich einer Platte (70), verbunden mit Platte (66) und mit einer weiteren Platte hin und her beweglich entlang der erwähnten Achse zum Tragen des anderen der erwähnten Teile (82) und zur Bewegung der erwähnten Teile (78, 82) in eine berührende Beziehung mit der Grenzfläche (84).

20. Vorrichtung nach Anspruch 1, wobei die Statôrpole jeweils eine Vielzahl von daran angeordneten Spulen aufweisen und wobei die Vorrichtung ferner folgendes aufweist:

Mittel zur Verbindung der Spulen an einem der erwähnten Pole in Parallelschaltung und der Spulen an den anderen der Pole in Serie,
Mittel zur Verbindung der in Serie und parallel geschaltenen Spulen miteinander und,
Mittel zum Anlegen einer Einphasen-Wechselstromleistung an einer der in Serie und parallel geschalteten um so eine Translationsschwingungskraft anstelle der Orbitalkraft in der Ebene zu erzeugen.

21. Vorrichtung nach Anspruch 1, wobei die elektromagnetischen Krafterzeugungsmittel (20) Mittel (96, 98, 100) aufweisen, zum Steuern der Geschwindigkeit des erwähnten einen Teils (78) in der Orbitalebene.

22. Vorrichtung nach Anspruch 21, wobei die elektromagnetischen Krafterzeugungsmittel (20) mindestens eine Spule aufweisen, an die Wechselstromleistung mit einer Grundfrequenz angelegt wird, wobei die Steuermittel (96, 98, 100) Mittel aufweisen, die auf ein erstes Signal ansprechen, welches in Beziehung steht mit der Größe des Stromes bei der dritten Harmonischen der Grundfrequenz und ferner ansprechend auf ein zweites Signal, welches in Beziehung steht mit dem Phasenwinkel zwischen der Spannung an der Spule bei der Grundfrequenz und dem erwähnten Strom auf der dritten Harmonischen zur Steuerung der Frequenz der Wechselstromleistung.

23. Vorrichtung nach Anspruch 22, wobei die Steuermittel (96, 98, 100) ferner Mittel aufweisen zur Vergrößerung der erwähnten Frequenz dann, wenn das zweite Signal negativ und das erste Signal unterhalb einer bestimmten Größe ist und zum Verringern der Frequenz dann, wenn das erste Signal oberhalb der erwähnten bestimmten Größe ist.

24. Vorrichtung nach Anspruch 1, wobei die Grenzfläche (84) in der Orbitalebene enthalten ist.

25. Vorrichtung (102) nach Anspruch 1, wobei die Antriebsmittel (104, 106) erste elektromagnetische Krafterzeugungsmittel (104) und zweite elektromagnetische Krafterzeugungsmittel (106) aufweisen, wobei von diesen Mitteln jedes unabhängig fähig ist, eine Orbitalkraft in der Orbitalebene zu erzeugen, wobei die Vorrichtung ferner Mittel aufweist zum Anlegen von elektrischer Leistung an die ersten und zweiten elektromagnetischen Krafterzeugungsmittel (104, 106) zum Antreiben der Befestigungsmittel (108, 122, 126) für den erwähnten einen der erwähnten Teile (120) mit entweder Orbitalbewegung oder Translationsschwingungsbewegung.

26. Vorrichtung (102) nach Anspruch 25, wobei die ersten elektromagnetischen Krafterzeugungsmittel (104) einen ersten Motor (104) aufweisen, geeignet zum Antrieb durch dreiphasige elektrische Leistung und mit einem Stator und einem Anker (128), wobei der Anker (128) ein einziger Körper aus Magnetmaterial ist, der Stator den Anker (128) umgibt, der Stator ein einziger Körper aus Magnetmaterial mit drei umfangsmäßig voneinander beabstandeten Polen ist und mit einer Spule auf jedem Pol, wobei jeder Pol eine Stirnfläche besitzt und wobei schließlich der Anker umfangsmäßig beabstandete Stirnflächen aufweist und jeder Anker zu einer unterschiedlichen Polstirnfläche mit seiner Stirnfläche hinweist,
wobei ferner die zweiten elektromagnetischen Krafterzeugungsmittel (106) einen zweiten Motor (106) aufweisen und zwar mit einem Anker (130), einem Stator mit drei Polen und einer Spule auf jedem Pol des Stators des zweiten Motors,
wobei die Befestigungsmittel (108, 122, 126) eine Platte (108) aufweisen, verbunden mit dem Anker (128) des ersten Motors (104) und mit den Anker (130) des zweiten Motors (130) und zwar an beabstandeten Stellen, und wobei schließlich
die Vorrichtung ferner Mittel aufweist, um die Phasen der dreiphasigen Leistung auf unterschiedliche der Spulen des Motors (104) umzuschalten zum selektiven Antreiben der erwähnten Platte mit Orbitalbewegung oder mit translatorischer Schwingungsbewegung.

27. Vorrichtung nach Anspruch 26, wobei die Befestigungsmittel (108, 122, 126) eine Platte (126) aufweisen, die sowohl mit dem ersten Motor (104) als auch mit dem zweiten Motor (106) verbunden ist.

28. Vorrichtung nach Anspruch 1, wobei der Orbitalmotor (20) geeignet ist um durch einphasige Wechselstromleistung betrieben zu werden, wobei jeder der Statorpole (38, 40, 42) eine Vielzahl von Spulen (24, 26, 28) darauf gewickelt aufweist, und wobei der Motor ferner folgendes aufweist:

Mittel zur Verbindung der Spulen auf einem der erwähnten Statorpole in parallel und der Spulen auf den anderen Polen in Serie,
Mittel zur Verbindung der in Serie und parallel geschalteten Spulen miteinander, und
Mittel zum Anlegen der erwähnten Einphasen-Wechselstromleistung an eine der in Serien parallel verbundenen Spulen um die Translationsschwingungskraft anstelle der Orbitalkraft in der Ebene zu erzeugen.

29. Vorrichtung nach Anspruch 28, wobei ferner Mittel (96, 98, 100) vorgesehen sind zum Steuern der Bewegungsgeschwindigkeit in der Orbitalebene ansprechend auf Strom und Spannung an einer der Spulen.

30. Motor nach Anspruch 29, wobei die Steuermittel (96, 98, 100) Mittel aufweisen, die auf ein erstes Signal ansprechen, welches in Beziehung steht mit der Größe des erwähnten Stromes bei der dritten Harmonischen der Frequenz der Wechselstromleistung und wobei die Mittel ferner auf ein zweites Signal ansprechen mit einer Größe, die in Beziehung steht mit dem Phasenwinkel zwischen der Spannung an der Spule bei der Frequenz der Wechselstromleistung und dem Strom durch die Spule bei der dritten Harmonischen zur Steuerung der Frequenz der Wechselstromleistung.

31. Verfahren zum Reibungsschweißen eines Paares von Teilen (78, 82) mit einem thermoplastischen Material an den Oberflächen derselben und zwar zum Zwecke des Schweißens, wobei die folgenden Schritte vorgesehen sind:

Vorsehen elektromagnetischer Krafterzeugungsmittel (20), wobei die elektromagnetischen Krafterzeugungsmittel (20) folgendes aufweisen:

einen einzigen Körper aus Magnetmaterial der einen Anker (50) vorsieht mit einer Mittelachse senkrecht zu der erwähnten Orbitalebene und mit einer Vielzahl von Polen umfangsmäßig verteilt um 360°/N, wobei N die Zahl der Pole um die Achse herum ist, wobei N gleich oder größer als drei ist, und

wobei ein Stator (30) um den Anker (50) herum angeordnet ist und der Stator (30) ein Vielzahl von Polen (38, 40, 42) aufweist, und zwar jeweils entgegengesetzt angeordnet zu einem unterschiedlichen Pol, der Ankerpole;
Halten der Teile (78, 82) mit ihren Oberflächen in Berührungsbeziehung zusammen;

Erzeugen einer Orbitalkraft zum Vorsehen einer Orbitalbewegung des Ankers (50) bezüglich des Stators (30);
Halten der erwähnten Oberflächen in der Orbitalebene während die Orbitalkraft erzeugt wird und zwar durch eine Anordnung von biegsamen Mitteln (90), angebracht außerhalb der elektromagnetischen Krafterzeugungsmittel (20); Erzeugung einer Reibungskraft um zu bewirken, dass die Oberflächen der erwähnten Teile (78, 82) verschmelzen und zwar durch Antreiben von mindestens einem der Teile (78) mit dem Anker (50) und Halten des anderen der Teile (82) stationär, so dass mindestens eines der Teile (78) eine Orbitalbewegung ausführt und um Achsen senkrecht zu den Kontaktoberflächen eine Orbitalausführung ausführt und wobei die Reibungskraft ausreicht in ihrer Amplitude, um das Verschmelzen an den Oberflächen zu bewirken, wobei ferner die Orbitalebene senkrecht zu den erwähnten Achsen verläuft, und
Beenden der erwähnten Reibungskraft und Halten der Teile (78, 82) die miteinander verschweißt sind nachdem die Reibungskraft aufhört bis sie zusammen verschmelzen um eine Schweißung zu bilden.

Revendications

1. Appareil pour le soudage par friction de pièces (78, 82) au niveau d'une interface (84) entre elles, ledit appareil comprenant :

- des moyens (16) pour entraîner l'une desdites pièces (78) avec un mouvement orbital par rapport à l'autre desdites pièces (82) tandis que lesdites pièces sont maintenues en contact au niveau de ladite interface, lesdits moyens d'entraînement (16) comprenant des moyens (20, 30, 50, 24, 26, 28) de génération de force électromagnétique qui produisent une force orbitale dans un plan orbital, et
- des moyens (64, 66, 68, 70, 72, 90) pour monter la première desdites pièces afin d'exécuter un mouvement orbital en réponse à ladite force orbitale quand ladite interface (84) est dans ledit plan orbital,

dans lequel lesdits moyens de génération de force électromagnétique comprennent un moteur orbital (20) qui comprend :

-- un corps unique en matériau magnétique réalisant un induit (50) ayant un axe central perpendiculaire audit plan orbital et une pluralité de pôles distribués circonférentiellement suivant 360°/N autour dudit axe, N étant le nombre desdits pôles et égal ou supérieur à 3, et
-- un stator (30) qui est disposé autour dudit induit (50), comportant une pluralité de pôles (38, 40, 42) chacun à l'opposé d'un pôle différent parmi lesdits pôles de l'induit, ledit induit (50) étant attaché sur lesdits moyens de montage sur ladite première pièce (118) pour amener ladite pièce à exécuter un mouvement orbital dans ledit plan orbital,

dans lequel lesdits moyens de montage (16) comprennent une série d'organes flexibles (90) afin de supporter ledit guide (50) pour un mouvement orbital dans un plan, lesdits organes flexibles (90) étant montés à l'extérieur dudit moteur orbital (20).

2. Appareil selon la revendication 1, dans lequel les pôles dudit induit et les pôles dudit stator sont perpendiculaires audit plan orbital, et lesdits moyens de génération de force électromagnétique (20) incluent des bobinages de génération de flux magnétique (24, 26, 28) qui sont magnétiquement couplés aux pôles dudit stator (38, 40, 42) pour établir un flux dirigé à travers ledit guide (50) le long dudit axe.

3. Appareil selon la revendication 12, dans lequel ledit stator (30) est un corps unique en matériau magnétique qui entoure ledit induit (50) depuis lequel s'étendent lesdits pôles de stator (38, 40, 42) et qui définit un trajet de retour pour ledit flux.

4. Appareil selon la revendication 3, dans lequel lesdits pôles de stator (38, 40,42) et lesdits pôles de l'induit exécutent un déplacement relatif tout en exécutant un mouvement orbital, et comportent des faces opposées (44, 46, 48 ; 58, 60, 62) espacées les unes des autres par des entrefers, la largeur de ces entrefers, telle que mesurée le long d'une ligne perpendiculaire auxdites faces, étant supérieure à la pointe dudit déplacement dudit induit (50) en réponse à ladite force orbitale.

5. Appareil selon la revendication 4, dans lequel ledit induit (50) est généralement triangulaire dans un plan perpendiculaire audit axe, chacune des faces (58, 60, 62) dudit induit étant le long d'un côté différent dudit triangle.

6. Appareil selon la revendication 5, dans lequel lesdits pôles (38, 40, 42) sont disposés à 120° les uns des autres, ledit appareil comprenant en outre des moyens pour appliquer des phases différentes d'un courant électrique alternatif triphasé à chacun des bobinages (24, 26, 28) dudit stator.

7. Appareil selon la revendication 3, dans lequel ledit corps de l'induit et ledit corps du stator comprennent des empilements séparés de lamelles de matériau magnétique.

8. Appareil selon la revendication 6, dans lequel lesdits bobinages (24, 26, 28) sont connectés en circuit delta.

9. Appareil selon la revendication 6, dans lequel lesdits bobinages (24, 26, 28) sont connectés en circuit Y.

10. Appareil selon la revendication 2, dans lequel lesdits moyens de montage (16) comprennent une plaque (66) sur laquelle est connecté ledit induit (50), lesdits organes flexibles (90) supportant ladite plaque (66) pour un mouvement orbital dans un plan ensemble avec ledit induit (50), et un support massif (12) pour ancrer de manière fixe ledit stator (30) et pour ancrer lesdits organes flexibles (90).

11. Appareil selon la revendication 10, dans lequel lesdits organes flexibles (90) comprennent des organes à ressort ayant la même raideur dans toutes les directions dans le plan dans lequel ladite plaque (66) exécute son mouvement orbital.

12. Appareil selon la revendication 11, dans lequel lesdits moyens de génération de force électromagnétique (20) incluent des moyens formant bobinage de stator (24, 26, 28) alimentés en courant alternatif, et dans lequel lesdits moyens de montage (16), y compris ladite plaque (66), ledit induit (50), et ladite première pièce (78), ont une masse totale et une raideur qui définissent une fréquence de vibrations permanentes approximativement double de la fréquence dudit courant alternatif.

13. Appareil selon la revendication 11, dans lequel lesdits organes à ressort (90) sont une pluralité de tiges disposées autour dudit axe et parallèlement à celui-ci, lesdites tiges (90) étant fixées à l'une de leurs extrémités sur ledit support (12), et à leur autre extrémité sur ladite plaque (66).

14. Appareil selon la revendication 13, dans lequel différentes tiges parmi lesdites tiges (90) sont déplacées radialement à des distances différentes depuis ledit axe.

15. Appareil selon la revendication 14, dans lequel lesdites tiges (90) sont disposées symétriquement autour dudit axe, de sorte que des tiges qui sont adjacentes les unes aux autres dans une direction circonférentielle autour dudit axe sont respectivement plus rapprochées et plus éloignées dudit axe dans une direction radiale, en contrecarrant ainsi le basculement de ladite plaque (66).

16. Appareil selon la revendication 13, dans lequel ledit support (12) comprend :

- un corps de support plus massif que ledit induit (50) et lesdits moyens de montage (16),
- une structure tubulaire (18) connectée à ladite plaque (16) et ayant une ouverture s'étendant le long dudit axe, ladite structure tubulaire (18) étant connectée audit corps de support (12), lesdites tiges (90) étant disposées dans ladite ouverture dans ladite structure tubulaire (18) et étant connectées de manière fixe à celle-ci à une extrémité de chacune desdites tiges (90).

17. Appareil selon la revendication 16, dans lequel lesdits moyens de génération de force électromagnétique (20), y compris ledit induit (50) et ledit stator (30), sont disposés dans ladite ouverture dans ladite structure tubulaire (18).

18. Appareil selon la revendication 17, dans lequel ledit appareil de soudage comporte un châssis (10) connecté audit corps de support (12).

19. Appareil selon la revendication 18, comprenant en outre une monture (76) pour recevoir ladite première pièce (78), comprenant un plateau (70) connecté à ladite plaque (66) et un autre plateau mobile en va-et-vient le long dudit axe pour supporter l'autre desdites pièces (82) et pour déplacer lesdites pièces (78, 82) jusqu'en relation de contact au niveau de ladite interface (84).

20. Appareil selon la revendication 1, dans lequel les pôles dudit stator ont chacun une pluralité de bobinages sur

eux-mêmes, ledit appareil comprenant encore :

- des moyens pour connecter lesdits bobinages sur l'un desdits pôles en parallèle et les bobinages sur les autres desdits pôles en série,
- des moyens pour connecter les uns aux autres lesdits bobinages connectés en série et en parallèle, et
- des moyens pour appliquer un courant électrique alternatif monophasé aux bornes de l'un des bobinages connectés en série et en parallèle de manière à engendrer une force de vibration en translation au lieu d'une force orbitale dans ledit plan.

21. Appareil selon la revendication 1, dans lequel lesdits moyens de génération de force électromagnétique (20) comprennent des moyens (96, 98, 100) pour commander la vitesse de ladite première pièce (78) dans ledit plan orbital.

22. Appareil selon la revendication 21, dans lequel lesdits moyens de génération de force électromagnétique (20) incluent au moins un bobinage auquel un courant électrique alternatif est appliqué sous une fréquence fondamentale, et lesdits moyens de commande (96, 98, 100) comprennent des moyens qui réagissent à un premier signal en relation avec l'amplitude du courant à la troisième harmonique de ladite fréquence fondamentale et à un deuxième signal en relation avec l'angle de phase entre la tension aux bornes dudit bobinage à ladite fréquence fondamentale et ledit courant à ladite troisième harmonique pour commander la fréquence dudit courant alternatif.

23. Appareil selon la revendication 22, dans lequel lesdits moyens de commande (96, 98, 100) comprennent en outre des moyens pour augmenter ladite fréquence lorsque ledit deuxième signal est négatif et que ledit premier signal est au-dessous d'une certaine amplitude, et pour diminuer ladite fréquence lorsque ledit premier signal est au-dessus de ladite certaine amplitude.

24. Appareil selon la revendication 1, dans lequel ladite interface (84) est contenue dans ledit plan orbital.

25. Appareil (102) selon la revendication 1, dans lequel lesdits moyens d'entraînement (104, 106) incluent des premiers moyens de génération de force électromagnétique (104) et des deuxièmes moyens de génération de force électromagnétique (106), dont chacun est capable indépendamment de produire une force orbitale dans ledit plan orbital, ledit appareil comprenant encore des moyens pour appliquer un courant électrique auxdits premiers moyens et auxdits deuxièmes moyens de génération de force électromagnétique (104, 106) pour entraîner les moyens de montage (108, 122, 126) pour ladite première partie (120) soit avec un mouvement orbital soit avec un mouvement vibratoire en translation.

26. Appareil (102) selon la revendication 25, dans lequel lesdits premiers moyens de génération de force électromagnétique (104) incluent un premier moteur (104) adapté à être alimenté en courant électrique triphasé et comportant un stator et un induit (128), ledit induit (128) étant un corps unique en matériau magnétique, ledit stator entourant ledit induit (128), ledit stator étant un corps unique en matériau magnétique ayant 3 pôles déplacés circonférentiellement les uns des autres et comportant un bobinage sur chaque pôle, chaque pôle ayant une face, ledit induit ayant des faces espacées circonférentiellement les unes des autres, et chaque face de l'induit étant opposée à une face polaire différente, et
lesdits deuxièmes moyens de génération de force électromagnétique (106) incluent un deuxième moteur (106) ayant un induit (130), un stator ayant 3 pôles et un bobinage sur chaque pôle dudit stator dudit deuxième moteur, lesdits moyens de montage (108, 122, 126) incluent une plaque (108) connectée à l'induit (128) dudit premier moteur (104) et à l'induit (130) dudit deuxième moteur (130) à des emplacements écartés,
ledit appareil comprenant encore des moyens pour commuter les phases du courant triphasé vers des bobinages différents parmi les bobinages dudit premier moteur (104) pour entraîner sélectivement ladite plaque en mouvement orbital, ou en mouvement vibratoire en translation.

27. Appareil selon la revendication 26, dans lequel lesdits moyens de montage (108, 122, 126) incluent un plateau (126) qui est connecté à la fois audit premier moteur (104) et audit deuxième moteur (106).

28. Appareil selon la revendication 1, dans lequel ledit moteur orbital (20) est adapté à être alimenté en courant électrique alternatif monophasé, et dans lequel chacun des pôles dudit stator (38, 40, 42) dudit stator comporte une pluralité de bobinages (24, 26, 28) enroulés sur lui-même, ledit moteur comprenant en outre :

des moyens pour connecter lesdits bobinages sur l'un des pôles dudit stator en parallèle et les bobinages sur les autres desdits pôles en série, des moyens pour connecter les uns aux autres lesdits bobinages connectés en série et en parallèle, et

des moyens pour appliquer ledit courant électrique monophasé aux bornes de l'un desdits bobinages connectés en série et en parallèle de manière à engendrer une force vibratoire en translation au lieu d'une force orbitale dans ledit plan.

29. Appareil selon la revendication 28, comprenant en outre des moyens (96, 98, 100) pour commander la vitesse de déplacement dans ledit plan orbital en réponse au courant et à la tension aux bornes de l'un desdits bobinages.

30. Appareil selon la revendication 29, dans lequel lesdits moyens de commande (96, 98, 100) comprennent des moyens qui réagissent à un premier signal en relation avec l'amplitude dudit courant à la troisième harmonique de la fréquence dudit courant alternatif, et à un deuxième signal ayant une amplitude en relation avec l'angle de phase entre la tension aux bornes dudit bobinage à la fréquence dudit courant alternatif, et le courant à travers ledit bobinage à la troisième harmonique pour commander la fréquence dudit courant électrique alternatif.

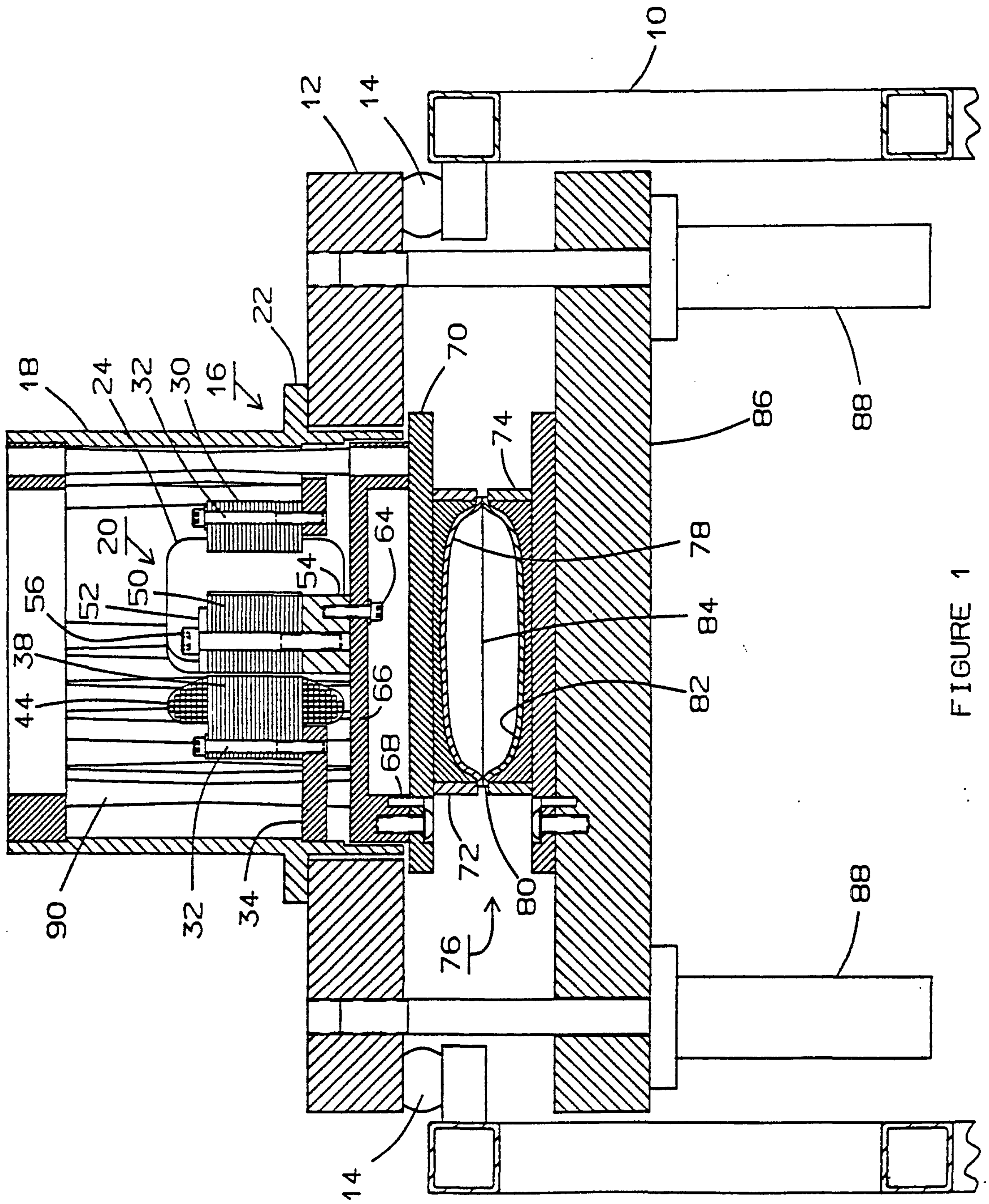
31. Procédé pour le soudage par friction d'une paire de pièces (78, 82) comportant une matière thermoplastique au niveau de leurs surfaces à souder, comprenant les opérations consistant à :

- procurer des moyens de génération de force électromagnétique (20), tels que ces moyens de génération de force électromagnétique (20) comprennent :

  -- un corps unique de matériau magnétique constituant un induit (50) ayant un axe central perpendiculaire audit plan orbital et une pluralité de pôles distribués circonférentiellement suivant 360°/N, N étant le nombre desdits pôles autour dudit axe et étant égal ou supérieur à 3, et

  -- un stator (30) qui est disposé autour dudit induit (50), ledit stator ayant une pluralité de pôles (38, 40, 42) qui sont chacun opposés à un pôle différent parmi lesdits pôles de l'induit ;

- maintenir lesdites pièces (78, 82) de telle sorte que lesdites surfaces sont en relation de contact mutuel ;
- engendrer une force orbitale pour provoquer un mouvement orbital dudit induit (50) par rapport audit stator (30);
- maintenir lesdites surfaces dans ledit plan orbital tandis que ladite force orbitale est engendrée par une série d'organes flexibles (90) montés à l'extérieur desdits moyens de génération de force électromagnétique (20);
- engendrer une force de friction pour amener lesdites surfaces desdites pièces (78, 82) en fusion en entraînant l'une au moins desdites pièces (78) avec ledit induit (70) et en maintenant l'autre desdites pièces (82) stationnaire, de sorte que l'une au moins desdites pièces (78) exécute un mouvement orbital autour d'axes perpendiculaires auxdites surfaces en contact, et ladite force de friction est suffisante en amplitude pour provoquer la fusion au niveau desdites surfaces, ledit plan orbital étant perpendiculaire audit axe, et
- cesser ladite force de friction et maintenir lesdites pièces (78, 82) qui sont en cours de soudure l'une à l'autre après avoir cessé ladite force de friction jusqu'à ce qu'elles se fusionnent ensemble pour former une soudure.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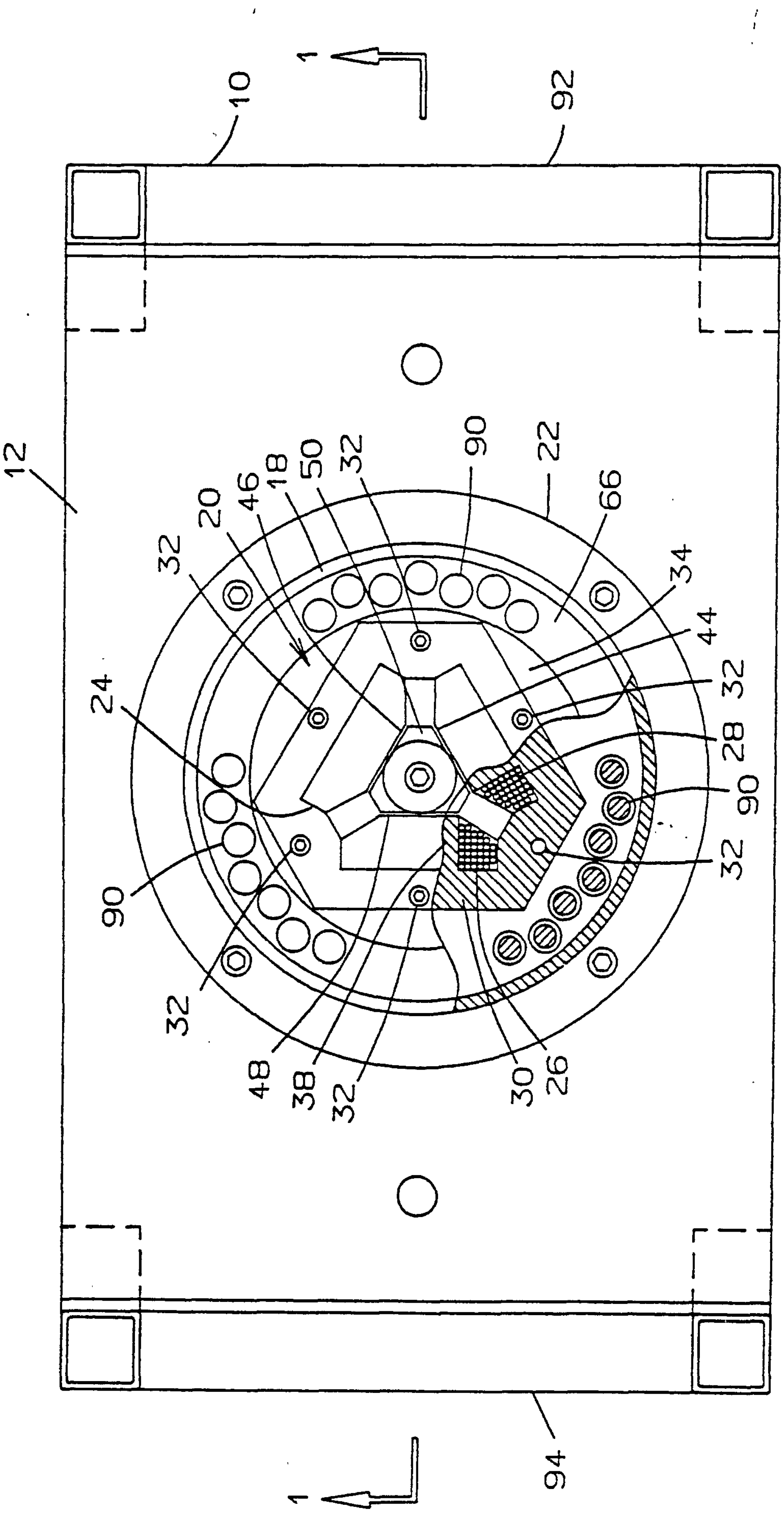
14

FIGURE 1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30
26
94
1

FIGURE 2

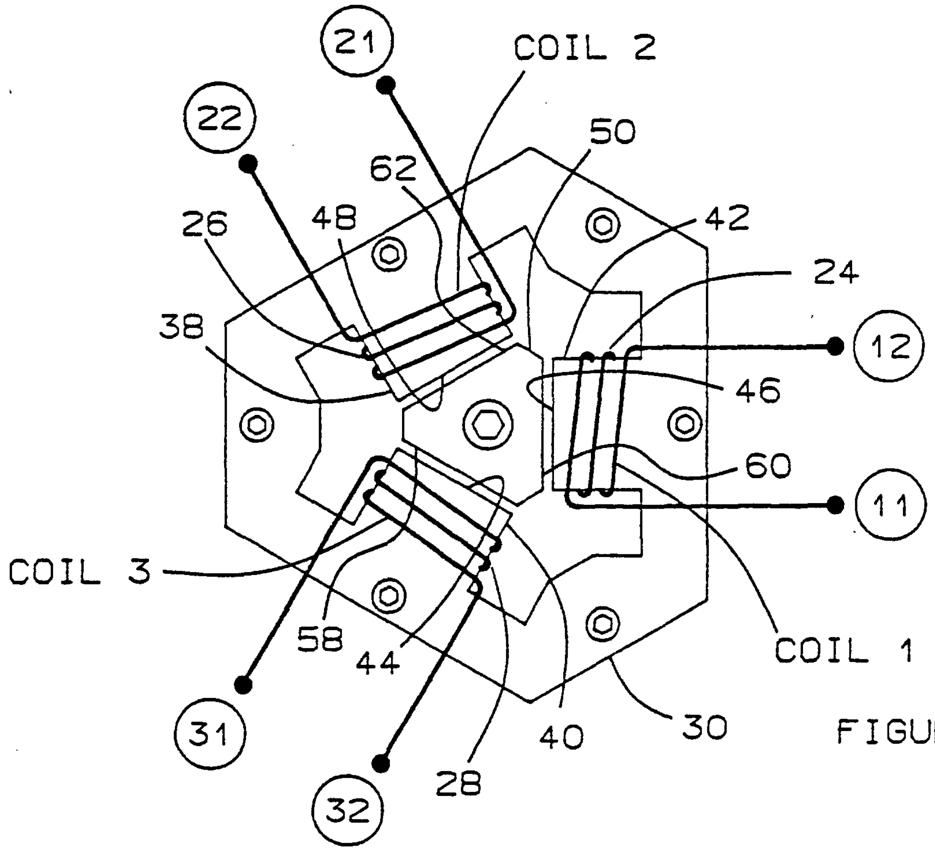

FIGURE 3

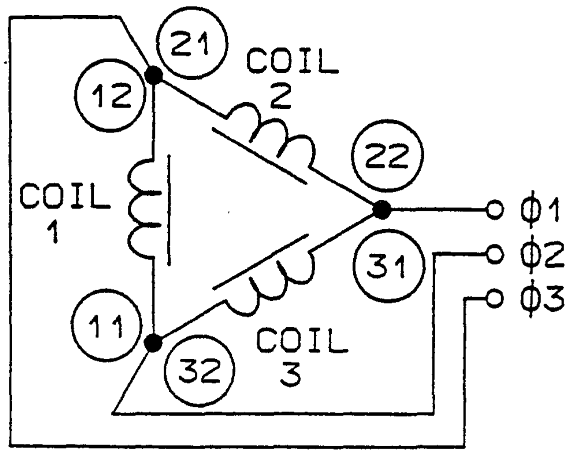

FIGURE 4

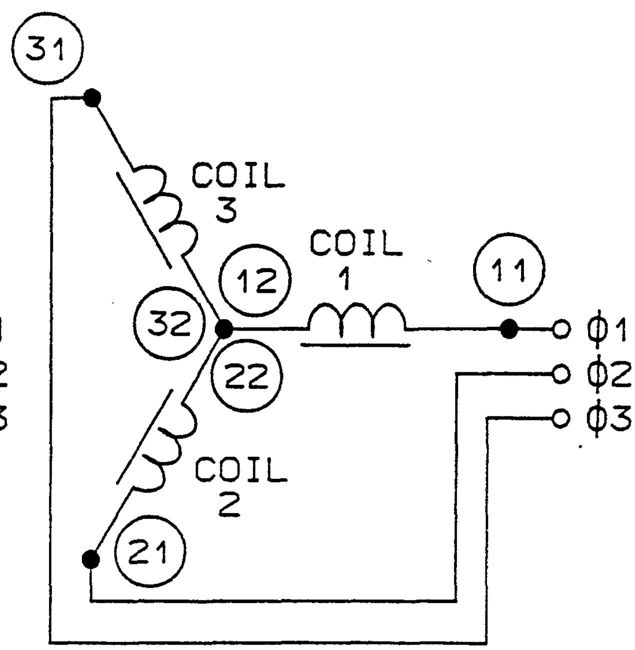

FIGURE 5

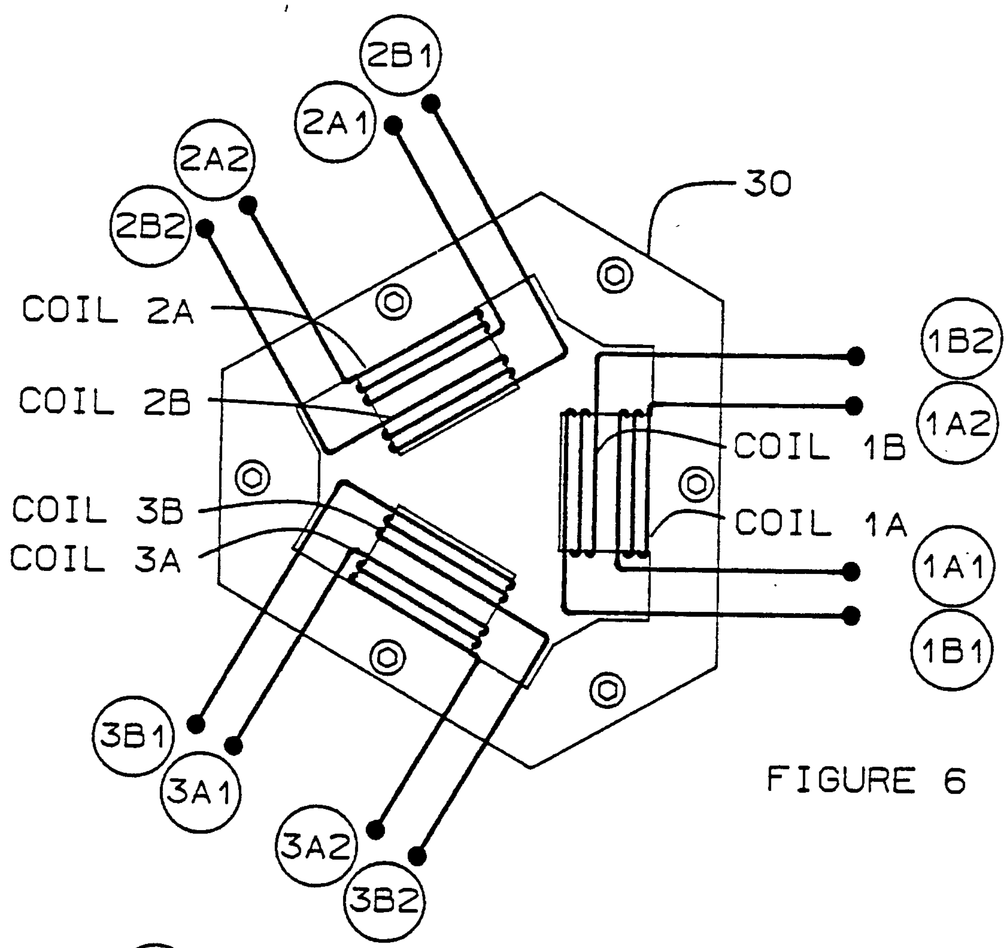

FIGURE 6

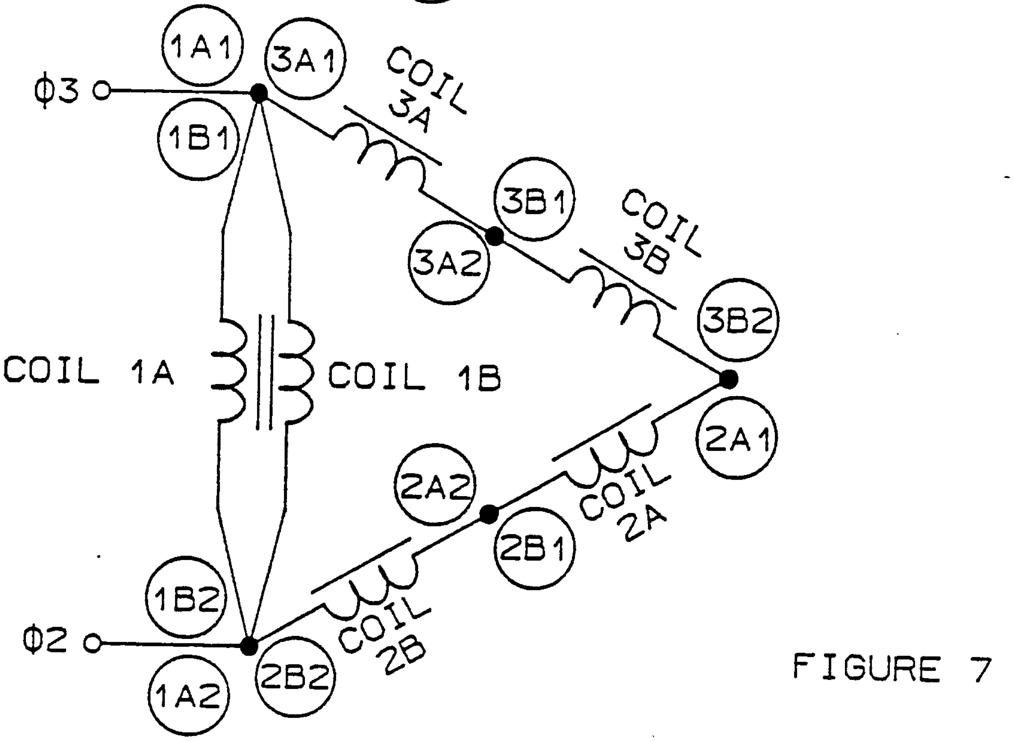

FIGURE 7

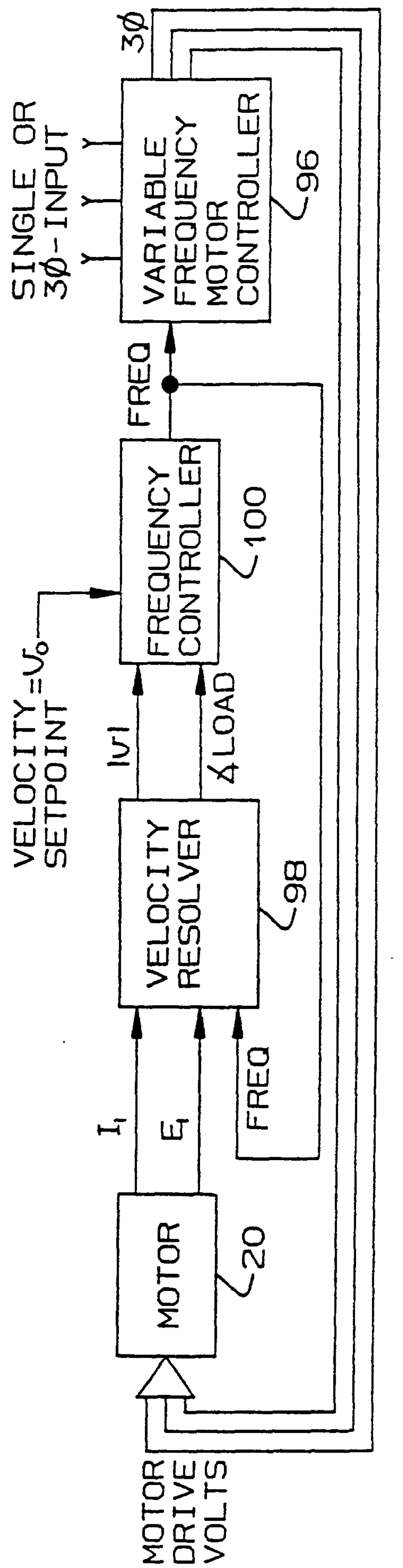
SINGLE OR
3Ø-INPUT
3Ø
VARIABLE
FREQUENCY
MOTOR
CONTROLLER
96
FREQ
FREQUENCY
CONTROLLER
100
VELOCITY
SETPOINT =V₀
|v|
∡LOAD
VELOCITY
RESOLVER
98
I₁
E₁
FREQ
MOTOR
20
MOTOR
DRIVE
VOLTS

FIGURE 8

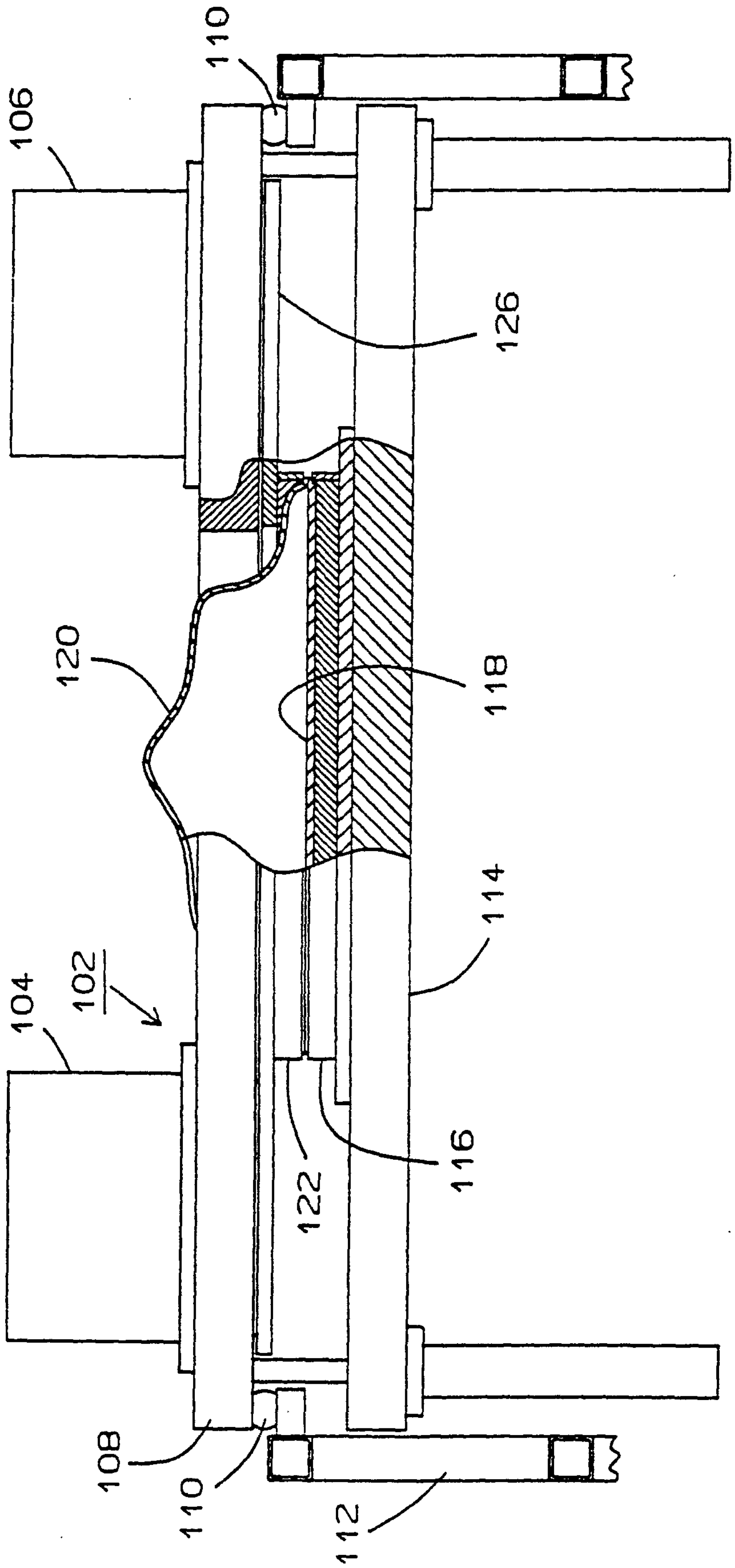

FIGURE 9

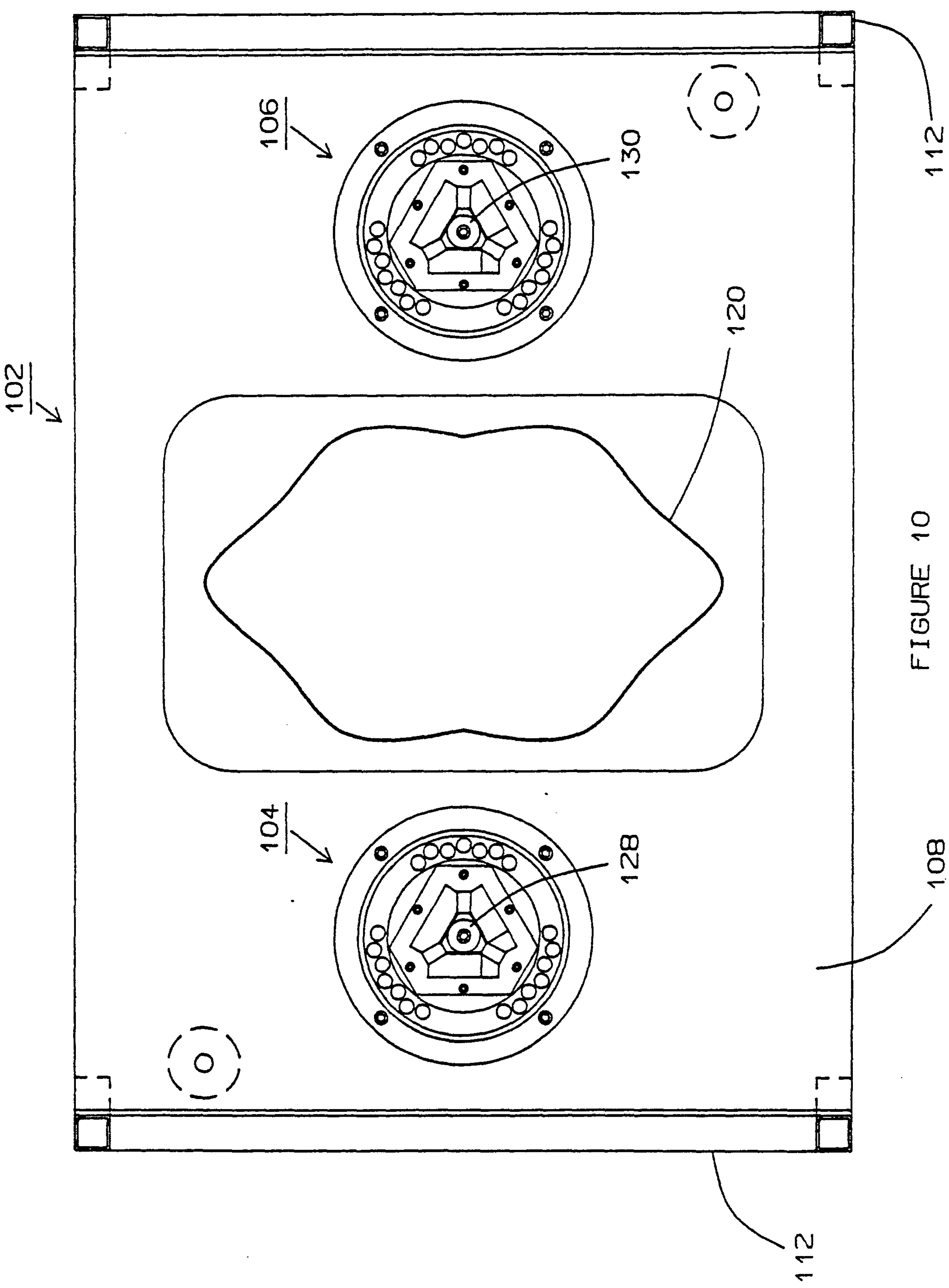

FIGURE 10

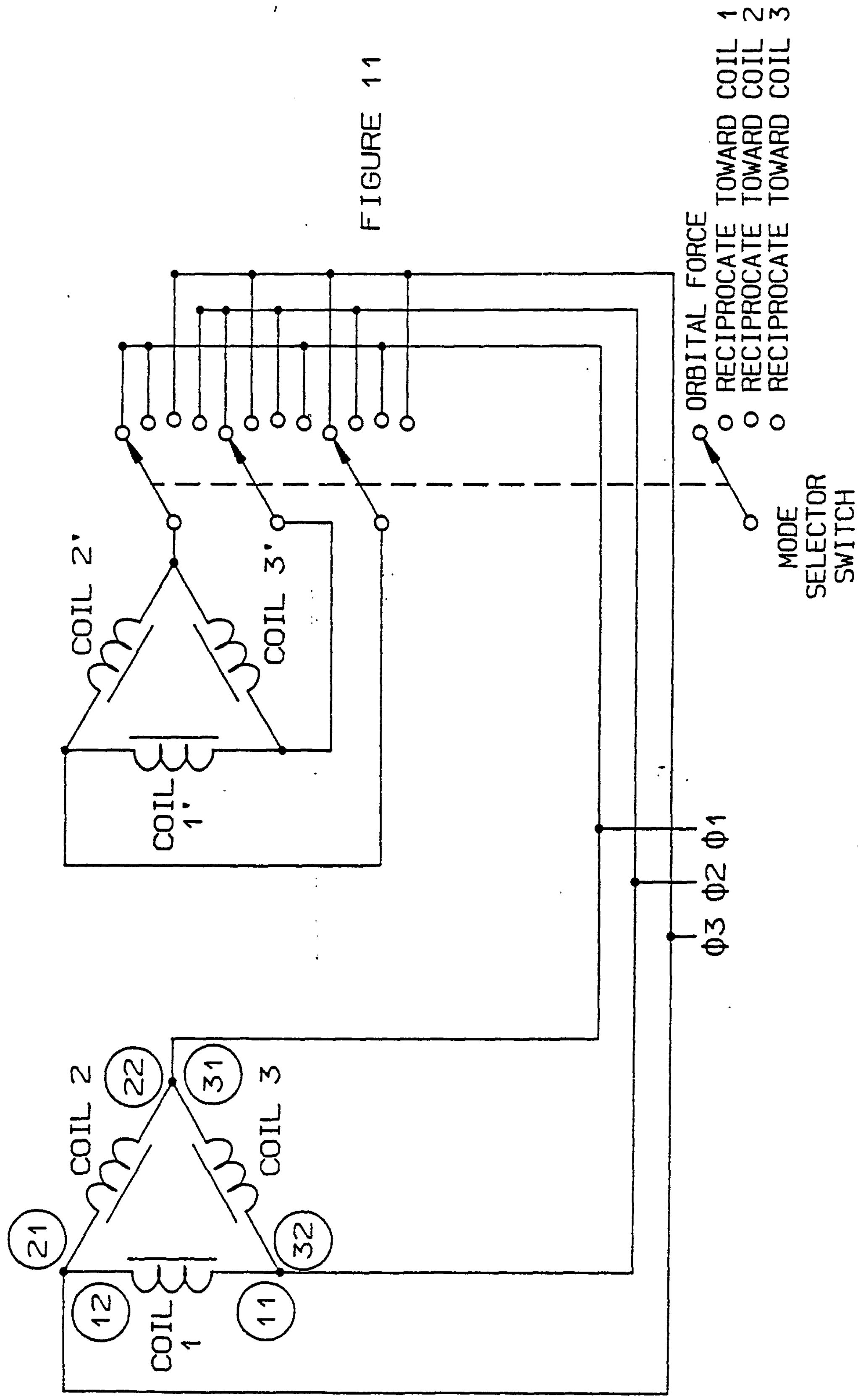
ORBITAL FORCE
RECIPROCATE TOWARD COIL 1
RECIPROCATE TOWARD COIL 2
RECIPROCATE TOWARD COIL 3
MODE SELECTOR SWITCH
COIL 2'
COIL 3'
COIL 1'
Φ1 Φ2 Φ3
COIL 2
COIL 3
COIL 1
21
22
31
32
12
11

FIGURE 11